Section II: Introduction

Designing a home for optimum comfort and value requires an understanding of:

1. The basics of heat gain in the home (Chapter 5).

2. Strategies you can use to control heat build up:

   - Landscape and site design (Chapter 6);
   - Insulation and radiant barriers (Chapter 7);
   - Reducing heat transfer through roofs (Chapter 8);
   - Reducing heat transfer through walls (Chapter 9);
   - Reducing heat transfer through windows and other openings (Chapter 10).

3. How you can use natural ventilation to reduce heat build up in interior spaces:

   - Airflow around buildings (Chapter 11);
   - Airflow in buildings (Chapter 12).

A summary of key strategies and recommended techniques from Chapters 5 through 12 is provided at the end of this section on page 57.

Chapter 5: Heat Basics

The primary goal in an energy-efficient home in Hawaii is to provide adequate temperature control and comfort while eliminating or reducing the use of air conditioning. This translates to two key design objectives:

1. Control heat build up using orientation, landscape, and design strategies that keep heat away from and out of buildings.

You can prevent heat build up through the careful placement of buildings on the site, through the use of shading strategies and devices, and by taking advantage of a site's natural features. Using materials which, because of their physical qualities, color, or texture are "cool," can help to prevent heat build up, as will limiting the use of materials that are inherently "warm." Insulation and radiant barriers are also powerful tools for reducing heat build up in interior spaces.

2. Use natural ventilation to remove heat and naturally cool interiors.

Natural ventilation can be used to remove heat and humidity from interiors and increase occupant comfort.

There are a variety of methods that can help to accomplish the objectives described in Chapters 6 through 12. But first, let's do a quick review of the basics. Where does heat in a home come from? How does it travel? And how is heat transfer measured?

Sources of Heat

Heat in a home comes from internal sources such as appliances, equipment, electric lighting, and people, as well as external sources such as the sun (Figure 5-1).

Fig. 5-1: Heat Sources for a Home

- Sunlight
- Hardscape surfaces
- Electric lights
- Appliances
- Equipment
- People

Heat Transfer

Heat travels into and through the home in a variety of ways, but it always travels from warmer locations to cooler locations. The greater the temperature difference, the faster the heat transfers. Air conditioned homes in Hawaii create significant differences between indoor and outdoor temperatures. In such conditions, blocking the transfer becomes critically important for comfort and energy savings. For this reason it is important to understand how heat transfers through, into, and out of the home. There are three types of heat transfer: conduction, convection, and radiation. (Figures 5-2 though 5-8).

Measuring Heat Transfer

When talking about how readily heat will transfer in a home, we usually speak in terms of a material's ability to transfer heat or its resistance to heat transfer.

The ability of a material to transfer heat is quantified in terms of its *U-value*, measured in Btus per square foot of area per hour (Btu/ft^2/hr). (A *Btu* [British thermal unit] is the amount of heat needed to increase the temperature of one pound of water by 1° F.) The higher the U-value, the more readily (faster) the heat will transfer through the material.

The *R-value* is a measure of a material's *resistance* to transferring heat. U and R are related by: R=1/U. The higher the R-value, the greater the resistance to heat transfer.

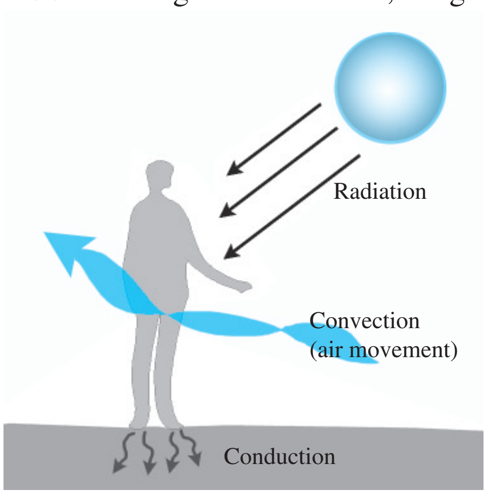


Fig. 5-2: Modes of Heat Transfer.

Heat is transferred to and through your home in the same way it is transferred to and through your body: conduction, convection, and radiation.

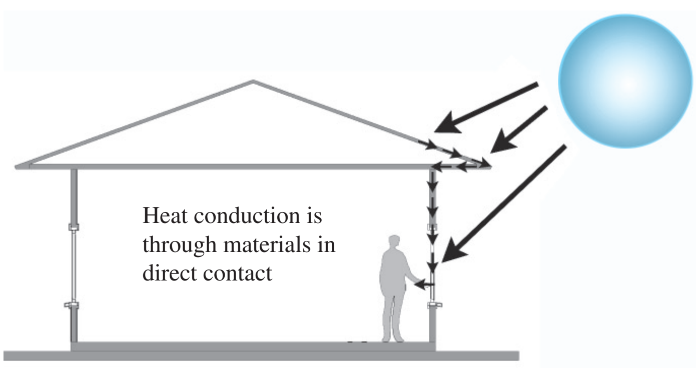


Fig. 5-3: Heat Transfer by Conduction.

In *conduction,* heat is transferred when warm and hot surfaces are in contact.

Insulation works by acting as a buffer between materials with significant temperature differences, such as hot exterior siding, and cool(er) interior wall surfaces. (Insulation may also reduce heat transfer through walls by radiation and convection).

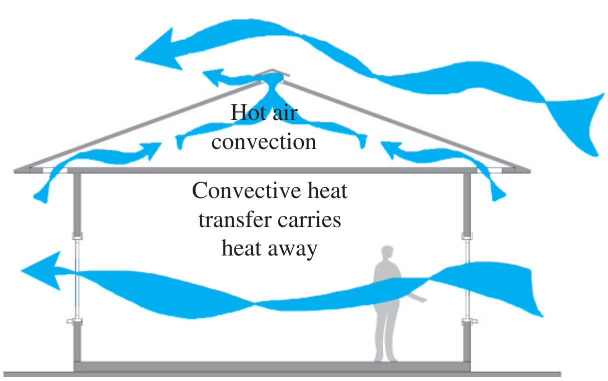


Fig. 5-4: Heat Transfer by Convection.

In *convection,* heat is transferred through a fluid (air or water). Warm fluids rise, cooler fluids sink.

Venting hot air can prevent heat build up in attics and occupied spaces. Natural ventilation uses convective heat transfer to carry heat away.

Heat from the sun radiates through space as electromagnetic energy in the near infrared range (near IR). Heat re-radiated from hot surfaces is in the form of electromagnetic energy in the far infrared range (far IR).

Understanding the difference between near infrared solar heat and far infrared heat radiated by materials that have been warmed by the sun is critical for selecting glazing that can prevent the buildup of heat in building interiors (see Chapter 10).

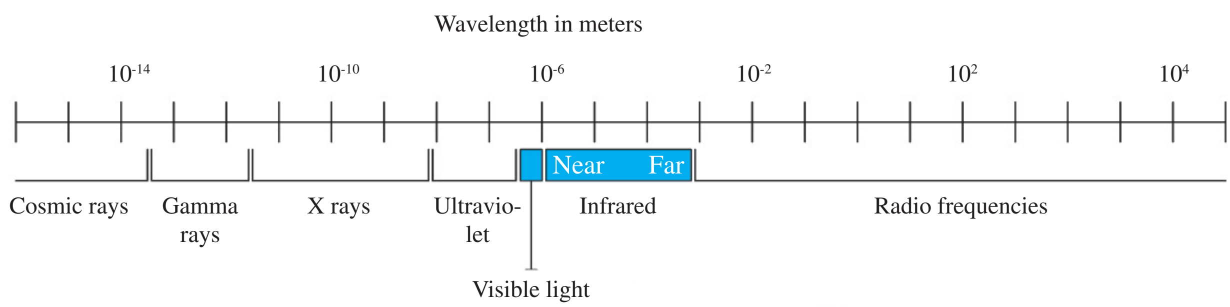
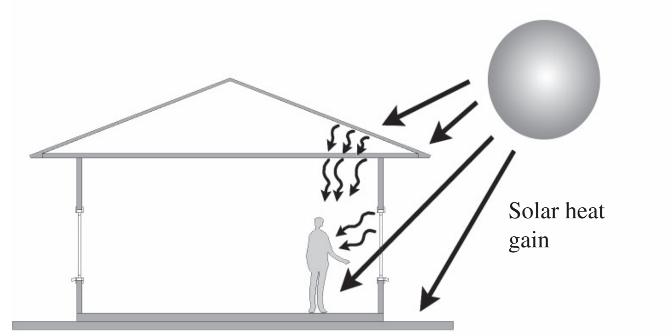


Fig. 5-5: Electromagnetic Spectrum.

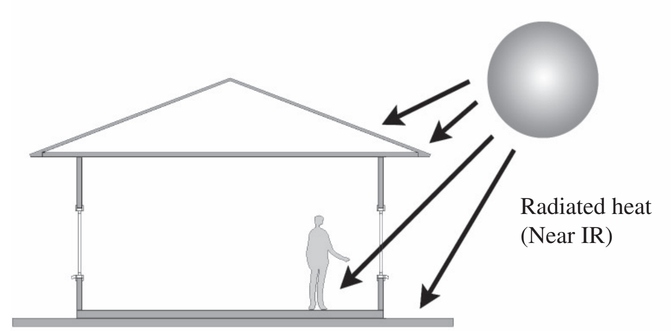
Fig. 5-6: Heat Transfer by Radiation.

In *radiation,* heat is transferred in the form of invisible electromagnetic waves. When the energy of radiation strikes an absorbing material, it is converted to heat. People absorb radiant heat from sunlight, hot walls, and ceilings.



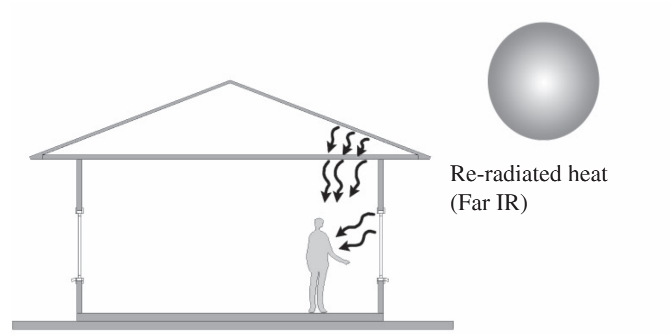
Radiated heat (near IR radiation): Sunlight (solar radiation) heats up surfaces exposed to the sun, such as roofs, walls, and pavement.

Radiant barriers reflect the sun's radiant heat protecting homes from solar radiation.



Re-radiated heat (far IR radiation): Objects heated by the sun re-radiate heat at a different wavelength.

Careful selection of low thermal mass materials can help avoid storage, build-up, and re-radiation of heat from building materials.



Chapter 6: Landscape and Site Design

Heat gain can be reduced with thoughtful building placement and site layout, through landscaping design, and through careful selection of materials for paving outdoor surfaces. See Table 6-A for a comparison of cooling elements.

Building Orientation and Shape

Recommended Technique: Limit heat build-up by orienting longer sides of the home north and south.

Solar Insolation* Btu/Sq. Ft. per day
21° Latitude

	East	South	West	North	Horizontal
Winter	780	1381	780	197	1374
Summer	950	309	950	591	2051

**Insolation* is the amount of solar radiation striking a surface.

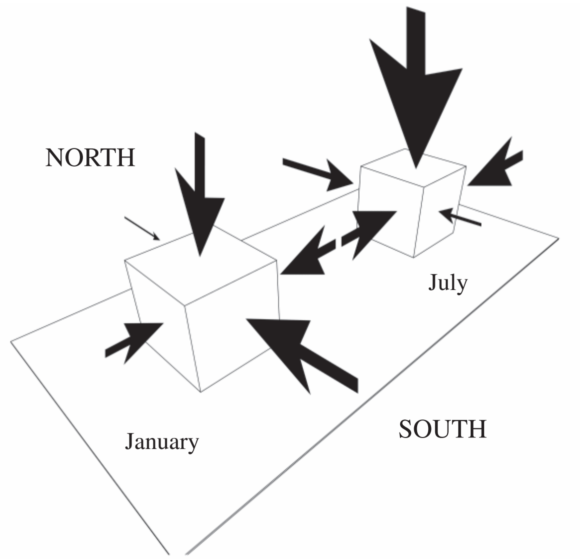
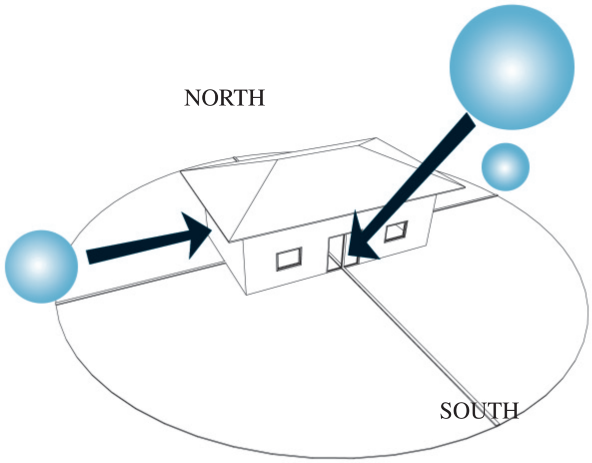


Fig. 6-1: Building Orientation and Solar Heat Gain.

Solar heat gain has the largest impact on surfaces perpendicular to the sun's rays. In Hawaii these are the roof, the east and west walls, and the south wall (especially during winter months).

Fig. 6-2: Building Shape and Solar Heat Gain.

Homes oriented with the narrow sides facing East-West will reduce low sun angle exposure and provide the best shading opportunities.



Elongated floor plans with the narrow sides facing within 15 degrees of East-West will minimize heat gain from the low angle morning and afternoon sun.

Although the south facade receives high solar insolation in the winter, this value can be reduced with roof overhangs. For more information on shading see Chapters 9 and 10.

Landscape Elements

Recommended Technique: Use existing or new landscape elements (trees) to shade the building.

Shaded areas stay cooler

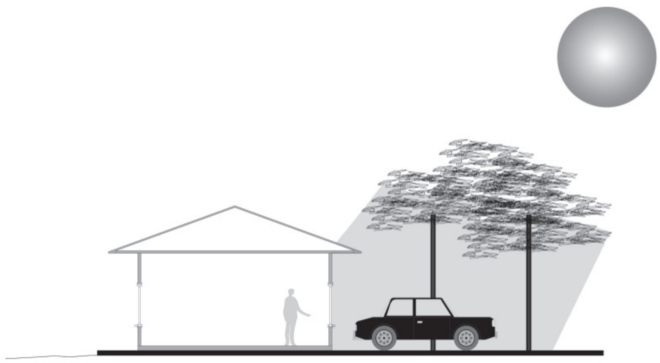
Fig. 6-3: Shading the Home with Landscaping.

Shading walls and roofs with plantings, such as shrubs, shade trees, and trellises supporting plants such as bougainvillea, can reduce solar heat gain.

Recommended Technique: Shade hardscapes, such as walls and paved areas.

Fig. 6-4: Shading Hardscapes with Landscaping.

Plantings, such as trees and shrubs, absorb solar radiation and shade the ground, lowering surface temperatures. Plants also cool the air around them through transpiration of water vapor.

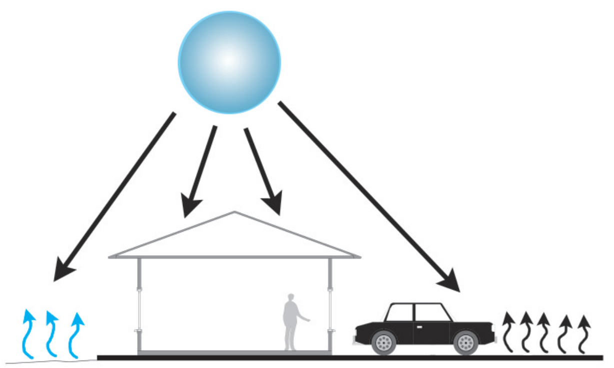


Shaded areas stay cooler

A single mature tree can provide nearly $300 annually in energy and resource values in terms of cooling, erosion and pollution control, and wildlife shelter. (Source: U.S. EPA, 1992)

Note: Prune lower branches to avoid blocking natural breezes.

Recommended Technique: Limit the area of unplanted and paved exterior surfaces. Provide generous areas of planting and ground cover to help reduce temperatures on the site.



The air temperature around unshaded landscaped areas are up to 10˚ cooler than unshaded hardscape areas.

Fig. 6-5: Hardscapes and Solar Gain.

Air temperatures above unshaded hardscape surfaces are up to 10˚ hotter than air temperatures above unshaded landscape areas, and up to 26˚ hotter than shaded landscaped areas.

Non-planted surfaces affect temperature and visual comfort. Dark materials, such as asphalt, absorb, conduct, and re-radiate heat. But they are easier on the eye. Light materials, such as concrete, absorb, conduct, and re-radiate significantly less heat but can cause glare.

Recommended Technique: Use porous paving materials to reduce thermal mass, heat gain, and glare.

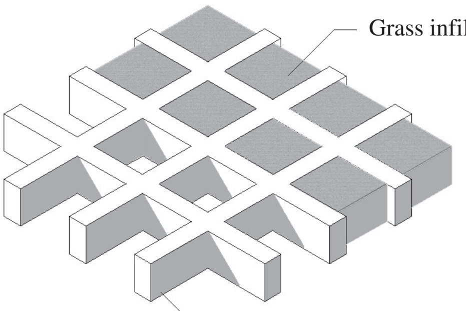


Fig. 6-6: Porous Paving.

Usually made of plastic or concrete, porous pavers have a grid-like pattern that allow vegetation to grow in the "pores" of the product. They are appropriate for areas of light traffic such as parking lots and driveways.

Porous paving is a good substitute for standard concrete or asphalt paving. Porous pavers reduce hardscape surfaces without sacrificing "drivable" areas.

Table 6-A: Comparing the Benefits of Site Elements for Air Conditioned Homes

Site Element	Potential Cooling Benefit
Trees and plantings	Carefully placed trees that provide both shading and evaporative cooling can reduce cooling energy requirements between 10% and 50%.
Light hardscapes	Computer simulations show light colored outdoor surfaces can reduce cooling energy use between 30% and 50% when compared to the same amount of dark colored surfaces. EPA, 1992
Porous Pavers	Porous pavers suitable for light traffic areas increase landscaping and provide added reductions in cooling energy use.

Chapter 7: Insulation and Radiant Barriers

Insulation and radiant barriers can significantly reduce heat buildup in the home. Many of the recommended practices in Chapters 8 and 9 incorporate these materials. To use insulation and radiant barriers effectively, it is important to understand these materials and how they work.

Insulation

Insulation works by resisting the transfer of heat through building walls, roofs, and ceilings. As discussed in Chapter 5, this "resistance" is stated in R-values. The higher the R-value, the greater the ability of the material to insulate. Insulating products have relatively high R-values compared to other building materials, such as concrete and steel. There are pros and cons to specific insulation types. For example, different insulation materials with the same thickness will have different R-values. A comparison of insulation types is summarized in Table 7-A. For construction details, see Chapters 8 and 9.

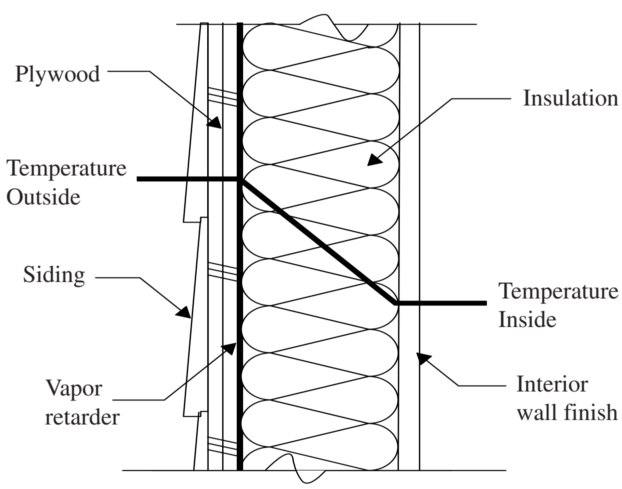
Insulation products come in a variety of forms, typically, rolls or batts, loose-fill, and rigid boards, providing ease of installation in a variety of applications. For example, loose-fill, which can be blown into the walls or attic of an existing structure, is a good option for renovation projects. Rigid foam, which provides more insulation per inch of thickness and may have structural properties, is easy to apply over framing members during the construction of a new home.

Insulation in air conditioned homes creates significant temperature differences between the interior and exterior of a home (see Figure 7-1). The dew point — the point at which water vapor in the air condenses to form liquid water — can be a concern in insulated air conditioned homes. When air is cooled below the dew point, water vapor in the wall cavity can wet the insulation. Wet insulation loses its insulating characteristics. Also, accumulation of water within the wall can produce mold or mildew and damage the wall assembly. *Vapor retarders* are sheets of plastic or felt that are highly resistant to water vapor. If installed on the exterior (more humid) side of the insulation, they can prevent moisture from condensing within the wall assembly.

Fig. 7-1: Insulation is an Effective Barrier to Heat Transfer.

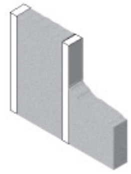
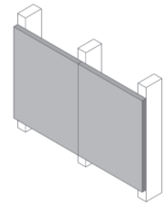
Insulation acts as a thermal buffer by reducing the amount of heat passing through walls and ceilings to the interior. Insulation is an effective barrier to conduction, convection, and radiant heat transfer.

For air-conditioned homes, a vapor retarder should be installed on the humid side of the insulation to prevent moisture condensation problems.



7
Insulation and Radiant Barriers

Table 7-A: Comparison of Typical Home Insulation Products

Type	**Batts** 	**Loose-Fill** 	**Rigid Board** 
Made from	Fiberglass, mineral wool	Fiberglass, mineral wool, or cellulose	Expanded polystyrene (EPS or beadboard), extruded polystyrene, polyisocyanurate, fiberglass
Description	Produced in widths and thickness to fit standard wood stud wall cavities (16" or 24" wide; 4" or 6" thick); kraft paper or foil backing helps in fastening to studs	Bulk	Lightweight, produced in large sheets
R-Value (per inch of thickness)	3.2	2.2 to 3.6	4 to 6.5
Energy Issues	Must be installed correctly to eliminate voids and hot spots	Unless installed with a binder, the material can be blown around or settle causing voids and hot spots	When installed as sheathing, provides continuous barrier, reducing thermal conduction; material's R-value can degrade over time. Polystyrene is better in moist conditions, and polyisocyanurate has a higher R-value.
Health and Environmental Issues	Several batt products include recycled content, a plus. However, with fiberglass, safety measures should be taken during installation and disposal to avoid undue exposure to fibers (and formaldehyde, found in the binders used in most fiberglass products). Fiberglass should not be used inside air ducts where it can break down and enter the airstream. Significant environmental concerns exist related to disposal of fiberglass insulation.	Several loose-fill products include recycled content, a plus. However, with fiberglass, safety measures should be taken during installation, demolition, and disposal to avoid undue exposure to fibers (and formaldehyde, found in the binders used in most fiberglass products). Fiberglass should not be used inside air ducts where it can break down and enter the airstream. Significant environmental concerns exist related to disposal of fiberglass insulation.	Many produced with CFCs (chlorofluorocarbons) and HCFCs (hydrochloro-fluorocarbons), generally believed to cause ozone depletion in the Earth's atmosphere. Rigid fiberglass and expanded polystyrene (EPS or beadboard) are produced without CFCs and HCFCs, and other rigid board manufacturers are working to eliminate this problem. Often contain urea formaldehyde in the foaming agent and may release toxic fumes when burned.
Application	New and remodels	New and remodels	New and remodels
Installation Information (See Chapters 8 and 9 for construction details.)	Fiberglass batts with paper or foil backing can be stapled to wood studs and joists when walls or ceilings are open.	Can be blown into walls and attics of existing structure and other difficult areas.	Nailed to framing or sheathing. Laid between ceiling joists.
Installed Cost	$0.80 to $1.00 per sq. ft.	$0.80 to $1.00 per sq. ft.	$1.00 to $2.00 per sq. ft.

Radiant Barriers

Radiant barriers are thin sheets of highly reflective material that prevent heat from building up in the home by "reflecting" rather than absorbing and then re-emitting heat. The lower the "emissivity" rating, the more effective the radiant barrier. Radiant barriers without insulating properties should be considered a supplement to, not a replacement for, insulation.

For ease of installation, the reflective material is normally adhered to a substrate, such as paper, plastic film, insulation, fabric, cardboard, or plywood. Radiant barriers can be installed in walls, but are more commonly used in attics. For construction details, see Chapters 8 and 9.

Table 7-B: Comparison of Radiant Barriers

Type	Roll/Reflective Insulation	Single-Sided Foil, Double-Sided Foil, & Multi-Layered Foil
Made from	Polyethylene air bubble pockets sandwiched between thin layers of reflective aluminum foil.	Foil with another material backing, such as kraft paper or polypropylene.
Physical description	4 and 6 ft. widths, 125 and 250 ft. lengths. Thin, lightweight, has little or no effect on building design loads. Impervious to insects, birds, and nesting rodents. Can be pressure washed.	Make sure material is listed as a radiant barrier.
Energy Issues	In addition to reflectivity, has an R-value of up to 15. Can act as a vapor and/or air barrier.	Not all foil barriers are alike; in general the shinier the material, the better the reflectivity. Look for emissivity below .10.
Health and Environmental Issues	Requires no special safety measures during installation.	Requires no special safety measures during installation.
Application	New construction and remodels.	New construction and remodels.
Installation Information (See Chapters 8 and 9 for construction details.)	Drape over rafters before the roof is installed, or stapled to the underside of rafters. Shiny side should face down. Useful in thin furred spaces above open beam ceilings. Must have soffit and ridge or gable vents and allow an airspace next to the foil side of material.	Drape over rafters before the roof is installed or stapled to the underside of rafters. Shiny side should face down. Must have soffit and ridge or gable vents and allow an airspace next to the foil side of material.
Installed Cost	$0.60 to $1.20	$0.60 to $1.00 per sq. ft.

Chapter 8: Heat Mitigation in Roofs

The roof is the greatest source of heat gain for homes in Hawaii, receiving about 1,700 Btu per sq.ft. per day. Solar radiation coming through the roof can account for a third of the heat build-up in a house. A roof can reach temperatures of 150^0 F, even when the ambient outdoor temperature is only 80^0 F. By paying special attention to the roof, you can make significant strides in preventing uncomfortable heat build-up in your home.

Several strategies address heat transfer through the roof. These include:

- Shading from existing trees, nearby structures, and topography
- Light colored roof surfaces
- Insulation
- Radiant barriers
- Roof vents

Using a combination (or all) of these strategies is the most effective way to achieve a comfortable, cool home, significantly reducing or even eliminating the need for air conditioning.

Shading

Recommended Technique: Shade roof to prevent heat build-up.

Fig. 8-1: Preventing Heat Gain by Shading the Roof.

One of the easiest ways to prevent the transfer of heat through a roof is to not let the roof get hot in the first place. Shading a roof will reduce its surface temperature.

Roof Assembly

Recommended Technique: Use roofing materials that will reflect the sun's heat rather than absorb and transfer it to the home's interior.

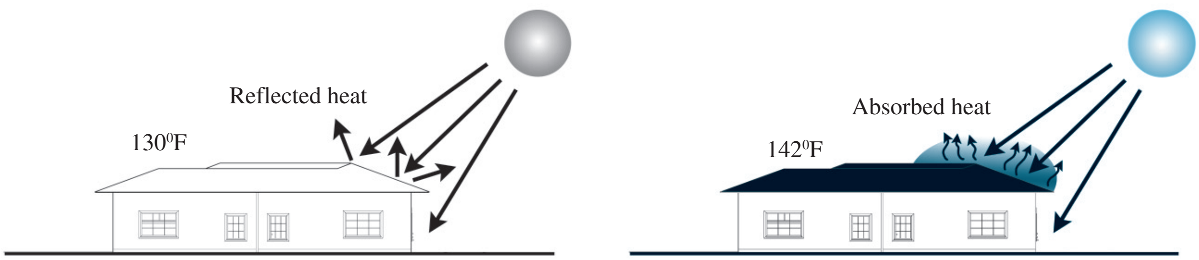


Fig. 8-2: Using Roof Materials to Reflect the Sun's Heat.

A light colored roof can reflect 25-30% of the sun's radiant heat and can be as much as 12˚ cooler than a dark colored roof. (*Source: Department of Education, State of Hawaii, 1979*.)

Both the color and the type of material affect amount of radiant heat reflected (measured in "reflectance"). Table 8-A compares the reflectance value of a number of roofing materials.

Table 8-A: Comparison of Different Roofing Materials, Showing White (Cooler Options).

Roofing material	Reflectance Value	Reflectance for White (Cooler) Option	Cost Increase for White (Cooler Option)
Asphalt Shingle	5-15%	31-35%	<1%
Clay tile	25-35%	70-80%	~35%
Concrete tile	10-30%	70-80%	~20%
Cementitious shingle	10-30%	60-80%	None
Metal sheet or shingle	70%	70-80%	None

Source: Green Seal, Energy Star® Homes Project

Recommended Technique: Insulate ceilings and attic spaces.

Insulation slows the transfer of heat from warm to cooler areas. When used in a roof assembly insulation can substantially reduce heat gain through a roof. Insulation can be effective when installed in either the roof (at the rafters) or in the ceiling. To keep a home cool, an R-value of 19 is recommended in roof construction.

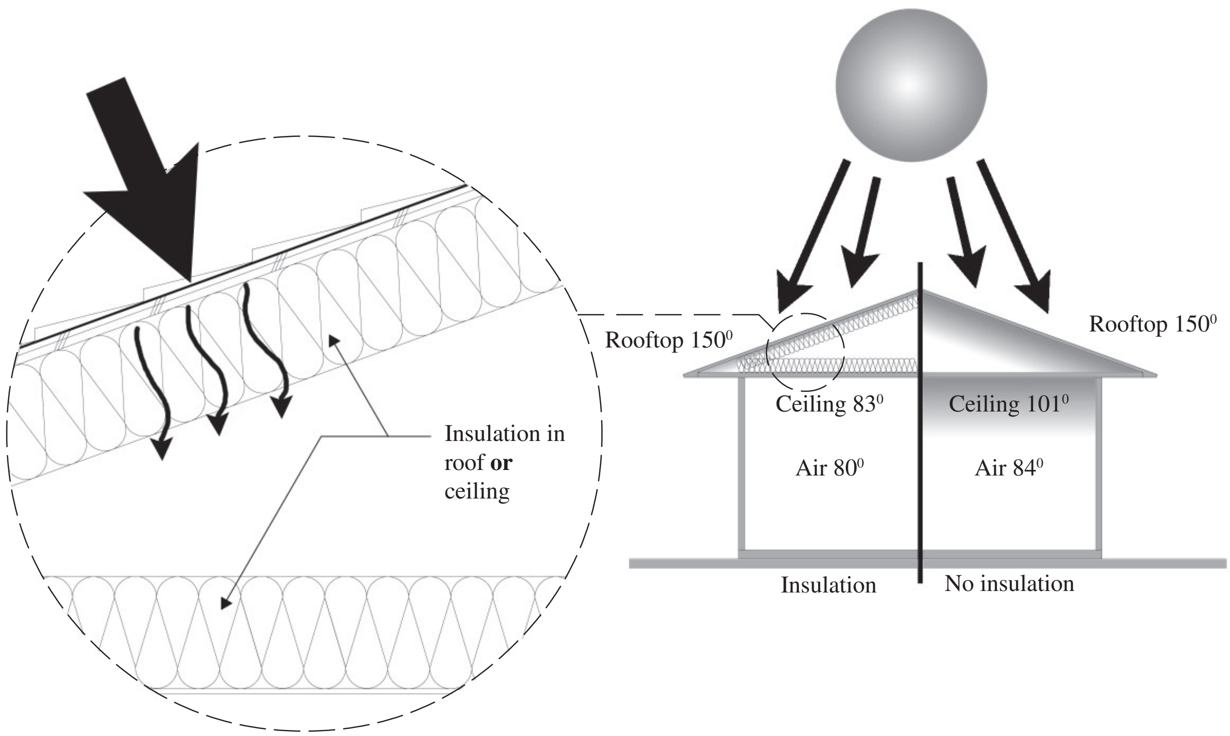


Fig. 8-3: Insulate Ceilings to Reduce Heat Gain.

Heat conducted through the roof heats the ceiling, which in turn radiates to the interior surfaces and occupants. R-19 insulation can reduce ceiling temperatures by more than 15˚ F (not including the impact of radiant barriers).

People are particularly sensitive to heat from overhead sources, and this reduction in real surface temperatures can make a room feel 9˚ F cooler.

Recommended Technique: Install radiant barriers in ceilings or attic spaces.

While insulation slows the rate of heat transfer, radiant barriers reflect the sun's radiant heat away from the home. *Proper installation is extremely important if a radiant barrier is to work effectively*. Installation details will depend upon the type of radiant barrier used (see Chapter 7, Table 7-B for a comparison of radiant barriers). However, two guidelines always apply:

1. Radiant barriers must be installed next to a minimum 3/4-inch air space. The air space can be located on either side of the radiant barrier, but best performance is achieved when the air space is on the exterior side of the radiant barrier.
2. Radiant barriers should be installed with the shiny foil side down to avoid dust build-up on the reflective surface, which reduces the barrier's effectiveness.

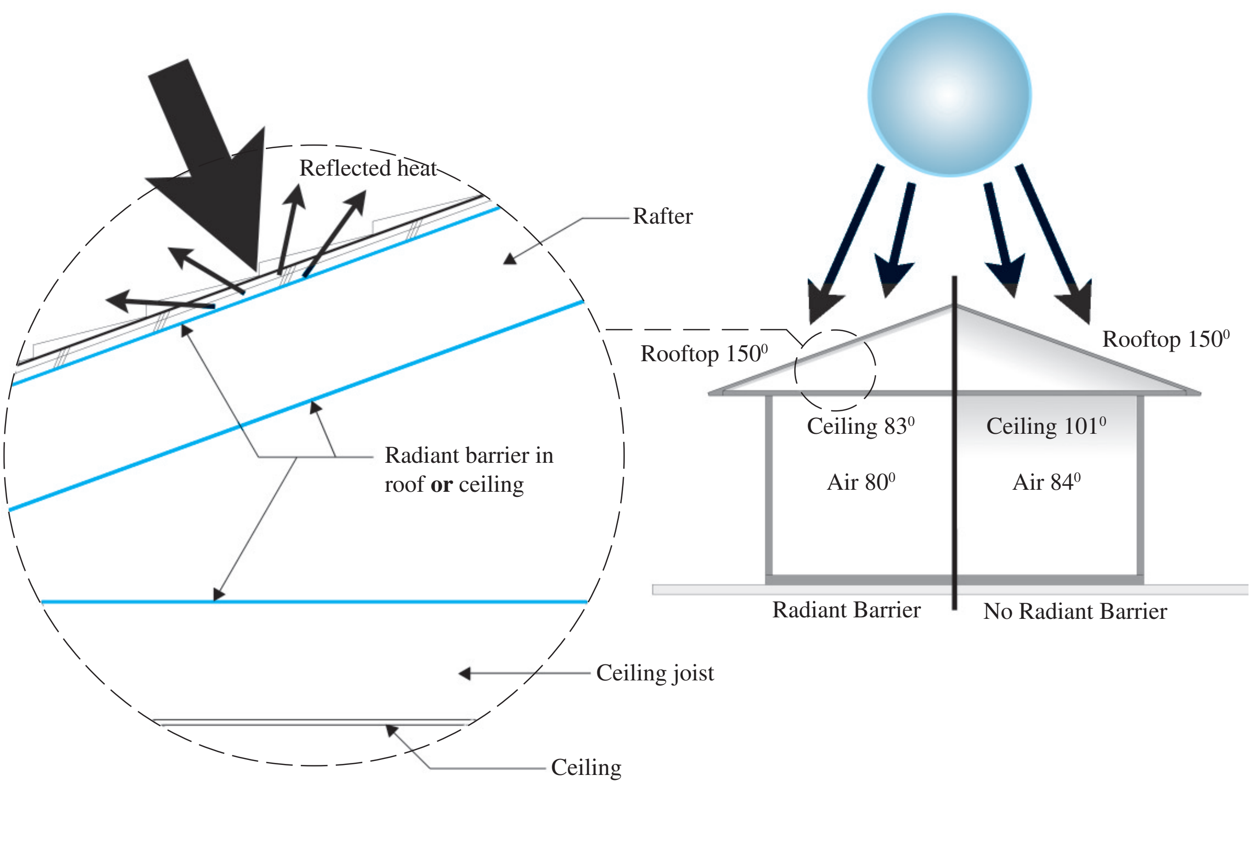


Fig. 8-4: Use Radiant Barriers in Ceilings to Reduce Heat Gain.

The reflective side of the radiant barrier must face an airspace to prevent the transfer of heat. In attics, this can be done by laying the material on top of the joists or by attaching it to the rafters as shown. Avoid damaging the radiant barrier during installation.

Properly installed radiant barriers can reflect up to 95% of the sun's radiant heat and reduce indoor air temperature by 4˚ F. A 4˚ reduction will make occupants will feel 9˚ cooler.

Because radiant barriers can reflect up to 95% of the sun's radiant heat, they reduce the amount of insulation needed to keep a home cool. Table 8-B shows the R-value of insulation recommended with and without a radiant barrier.

Table 8-B: Recommended Insulation R-values With and Without Radiant Barrier.

Roof Surface Color	**Absorptivity***	**Minimum R-Value of Roof Insulation**	
		With Radiant Barrier	**Without Radiant Barrier**
Black or Dark Gray	0.90	R-3	R-19
Medium Red, Green, Brown, Gray	0.75	R-2	R-15
Yellow, Buff	0.60	R-1	R-11
Light Gray	0.55	R-1	R-8
White (built-up roof)	0.50	R-0	R-7
White (tile, paint, plaster)	0.40	R-0	R-5
White (glazed brick, tile or metal)	0.30	R-0	R-3

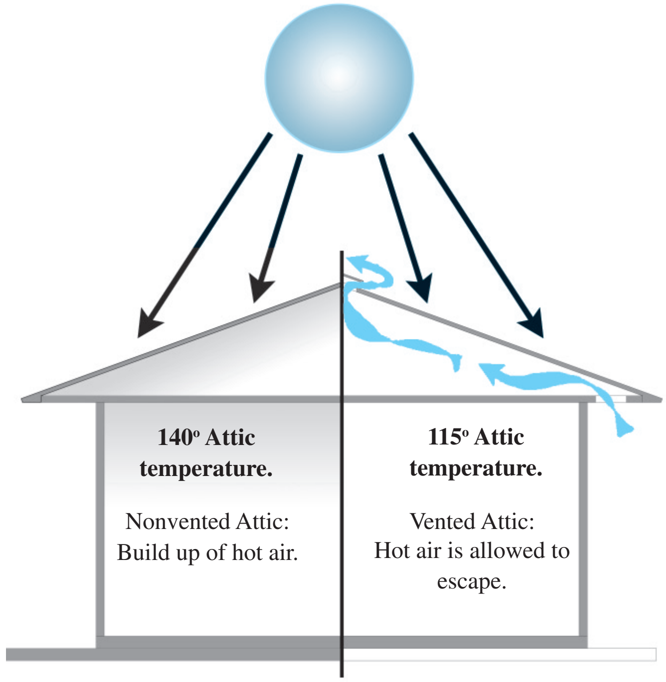
* *Absorptivity* is the amount of radiation absorbed by an object relative to the amount radiation striking its surface. The range for absorptivity is 0.0 to 1.0.

Recommended Technique: Ventilate roof properly.

There are several ways to ventilate roof and attic spaces. All techniques admit cool air and allow hot air to escape. A properly ventilated attic will keep the attic cooler and reduce moisture build-up.

Fig. 8-5: Roof Ventilation: Continuous Ridge and Soffit.

With a continuous ridge-and-soffit vent system, vents draw in cool air from the eaves and exhaust hot air through the roof's ridge. Air moves through the attic either through wind movement or through convection.



Source: Air Vent Inc., 1997

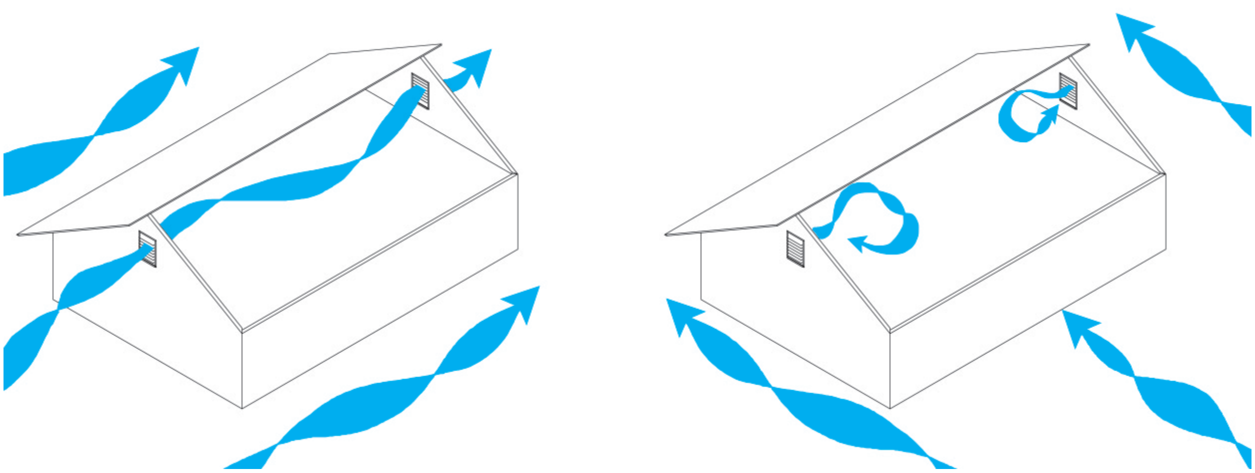


Fig. 8-6: Roof Ventilation: Gable End Vents.

Generous gable end vents can provide openings to vent hot air and admit a free flow of cooling outdoor air through attic spaces. However, when the wind direction is parallel to the roof gable, attic ventilation is limited.

Tips for installing ridge vents:

- Exterior baffles (Figure 8-7) deflect wind and rain, substantially increasing the effectiveness of ridge vents.
- Intake (soffit) and exhaust (ridge) vent areas should be equal. These areas should be calculated using the net unobstructed area and not the area of the vent itself. Vents often contain screens or grills that decrease their effective open areas.
- Ridge vents need baffles to stop water infiltration from wind-driven rain.
- If foam blocks are used to seal vent ends, make sure blocks are covered with a UV-resistant coating.
- Leave a 3/4-inch gap on each side of the roof peak.
- Alignment tabs help to maintain a uniform distance between vent panels, and allow for faster installation. If the vent does not have alignment tabs, leave a 1/8-inch gap between the panels to allow for expansion.

Recommended Technique: Integrate roof strategies.

Using a combination (or all) of the measures listed above is the best, most complete way to ensure a cool home. Using these materials and techniques will reduce heat gain and can reduce or eliminate the need for air conditioning.

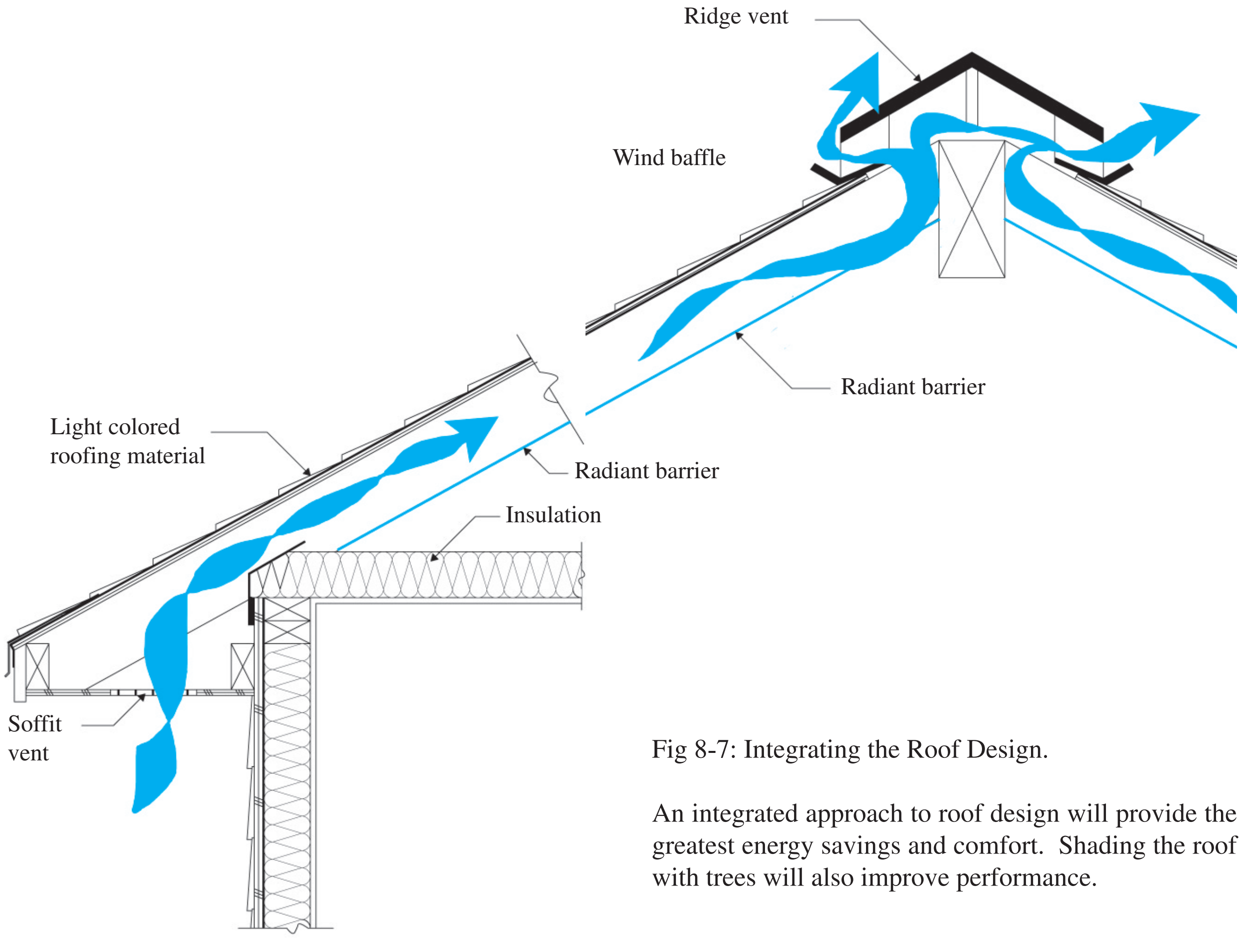


Fig 8-7: Integrating the Roof Design.

An integrated approach to roof design will provide the greatest energy savings and comfort. Shading the roof with trees will also improve performance.

Chapter 9: Heat Mitigation in Walls

In Hawaii, unshaded walls are exposed to high levels of solar radiation. During the winter months, south facing walls can receive over 1,300 Btu/sq.ft./day. During the summer, east and west walls receive nearly 1,000 Btu/sq.ft./day. If this heat is allowed to re-radiate into interior spaces, it can create discomfort in the home. The same techniques and materials used to keep roofs cool apply to walls. Keep walls cool with:

- Shading from architectural (see below) and landscape elements (see Chapter 6)
- Light colored wall surfaces
- Insulation
- Radiant barriers

Recommended Technique: Use design elements to shade walls.

Trellises, covered lanais, carports, and roof eave overhangs make effective shading devices for walls (Table 9-A shows the recommended overhang size for walls). See Chapter 10 for more information on shading devices.

Table 9-A Overhang Size for Walls.

Wall Height (feet)	Minimum Overhang Size (inches)	
	North	East, South, West
7	17	26
8	20	29
9	22	33
10	24	36
11	27	40
12	29	44
13	32	47
14	34	51
15	36	54

Recommended Technique: Use light colored wall finishes.

Fig. 9-1: Light Colored Surfaces Reflect Heat and Stay Cooler.

Recommended Technique: Insulate walls exposed to the sun.

By insulating walls exposed to the sun, you can lower the indoor temperature of the home significantly. For walls, insulating to R-11 is recommended. For more information on insulation, see Chapter 7.

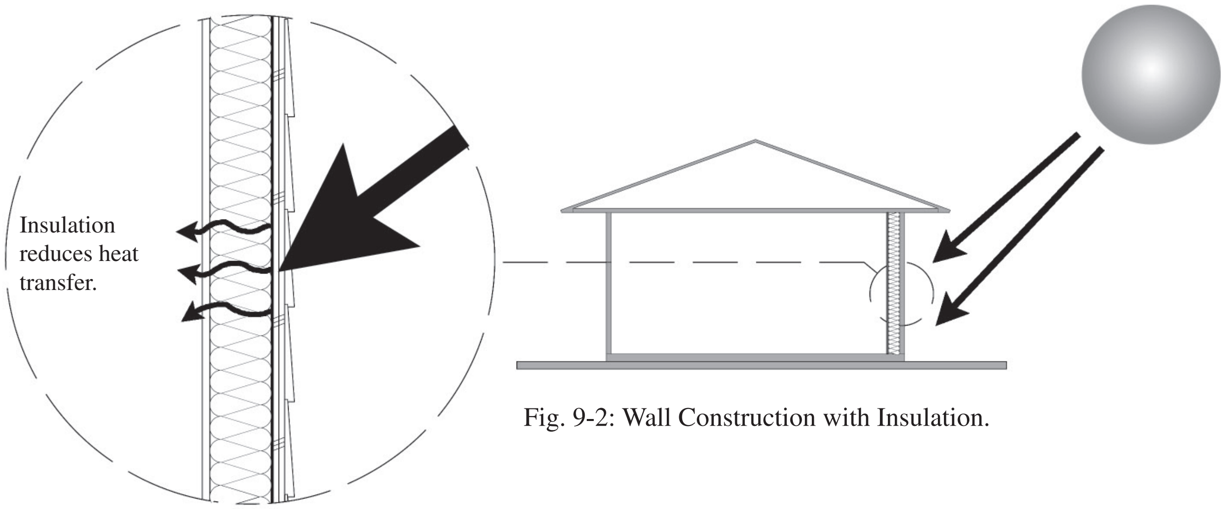


Fig. 9-2: Wall Construction with Insulation.

Recommended Technique: Install radiant barriers in walls exposed to the sun.

Just as with roofs, radiant barriers in walls can greatly reduce the heat transferred to the interior of a home. For more information on radiant barriers, see Chapter 7.

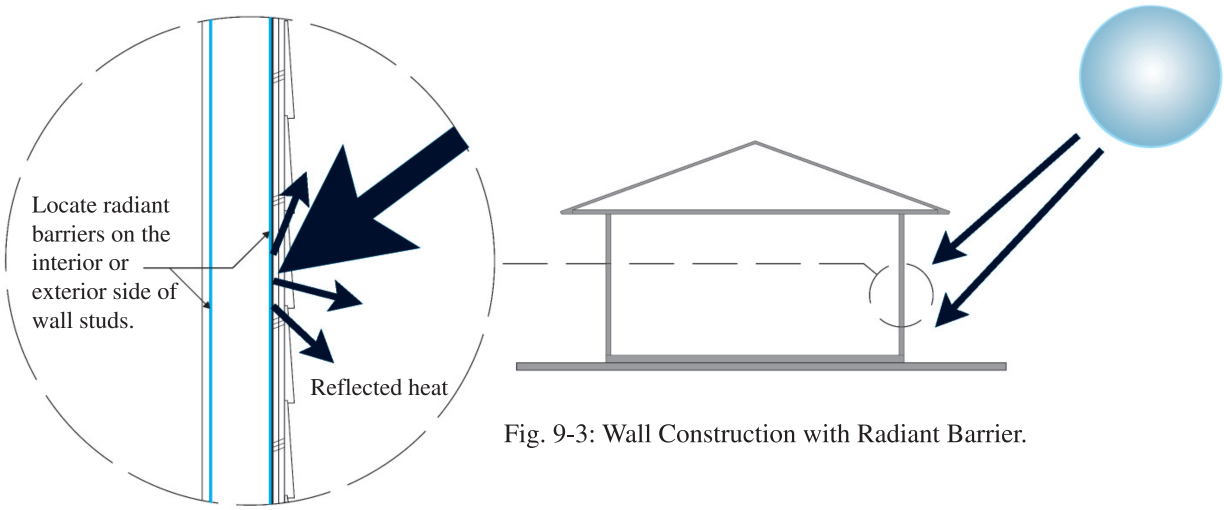


Fig. 9-3: Wall Construction with Radiant Barrier.

Chapter 10: Controlling Heat Gain for Windows and Other Openings

Windows provide access to views, natural light, and natural breezes. However, direct sunlight from windows can account for over half of the summer cooling energy load in an air conditioned home. This chapter discusses strategies to prevent heat build-up while still maintaining a connection to the outdoors and access to natural light. (Chapter 12 will discuss optimizing window placement and configuration as part of a natural ventilation plan.)

The strategies for preventing heat build-up through windows, skylights, and other openings (such as glazing in doors) include:

- Shading
- High performance glazing
- Limiting the size of openings

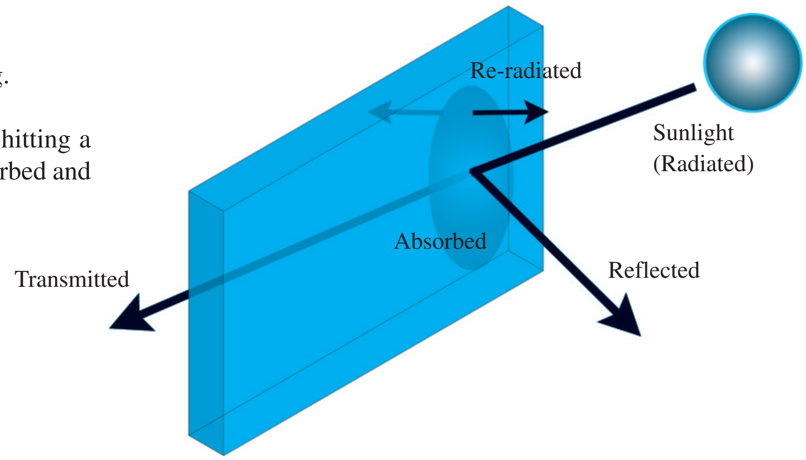


Fig. 10-1: Sunlight and Window Glazing.

The energy in sunlight (solar radiation) hitting a window is reflected, transmitted, or absorbed and re-radiated.

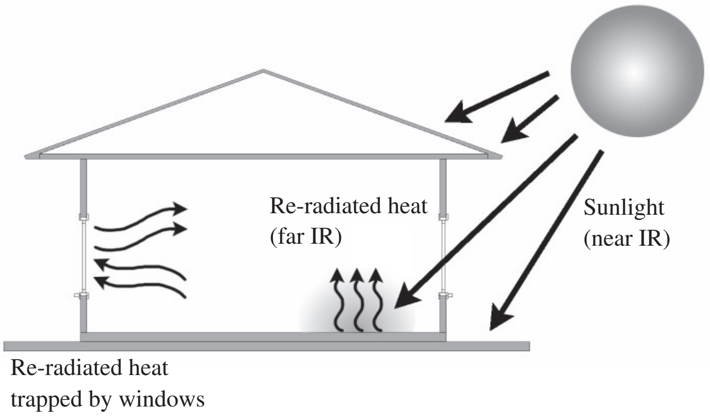


Fig. 10-2: Sunlight and Heat Production Inside the Home.

The solar radiation passing through a window is near infrared radiation (near IR). This heat is absorbed and then re-radiated from warmed interior surfaces as far infrared radiation (far IR). Near IR heat passes very easily through the glass into the home. Far IR heat does not pass easily through glass and gets trapped in the home. This is the same process that heats your car up when it is left out in the sun all day.

Table 10-A compares the percent reduction in solar heat gain using improved window options verses 1/4-inch single-pane glazing. Exterior shading provides the biggest reduction in heat gain. When exterior shading is not possible, combining strategies, such as partial exterior shading and/or interior shading and high performance glazing, can be effective.

Table 10-A: Comparing Improved Window Options to Conventional Glazing

System	Reduction in solar heat gain vs. 1/4-inch single-pane clear glazing
Exterior shading	80%
Reflective glazing/films	37-68%
Spectrally selective glazing	37-58%
Tinted glazing	26-37%
Interior light colored blinds, lowered but open	30%
Interior medium colored blinds, lowered but open	22%
Interior translucent shade	54%
Interior opaque shade, white	59%
Interior opaque shade, dark	15%

Source: ASHRAE Handbook of Fundamentals, 1989

Recommended Technique: Shade windows and other openings.

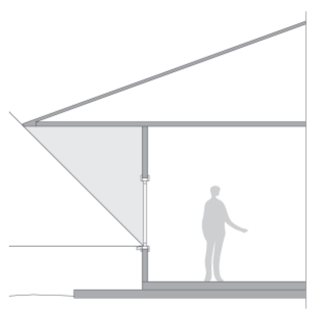
Exterior Shading

Exterior shading is the most effective method for reducing heat gain in a home through windows. To work, however, shading devices must be adapted to the sun's path and angle as it hits the surfaces of the home.

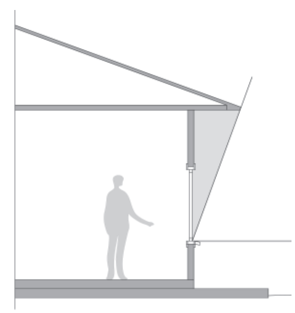
North- and south-facing windows are best shaded by horizontal devices, such as overhangs and trellises. East- and west-facing windows, which are subject to lower sun angles, are better protected by vertical shading devices, such as walls and fins (see Figures 10-3 and 10-4). For more information on sizing shading devices, see Appendix D.

Fig. 10-3: Window Shading: Horizontal Shading Devices.

Horizontal shading devices, such as overhangs, are good for blocking high angle sunlight. They work best on the north and south facades of the home.



To calculate the eave width needed to shade south-facing openings use a 45˚ angle.



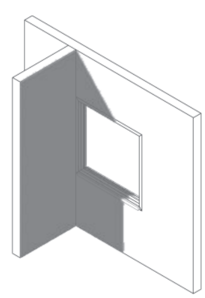
To calculate the eave width needed to shade south-facing openings use a 70˚ angle.

Fig. 10-4: Window Shading: Vertical Shading Devices.

Vertical shading devices such as walls and fins are good for blocking low angle sun on the east and west facades.

Vertical shading devices can also aid in natural ventilation (see Chapter 12).

Plan (top) view of vertical shading wall.



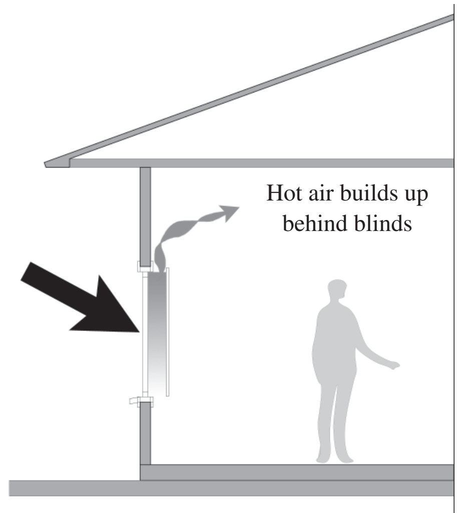
Isometric view of vertical shading wall.

Interior Shading

Fig. 10-5: Interior Shading.

Interior window treatments, such as shades, blinds and shutters, reduce heat build-up in the home by reducing the amount of direct sunlight entering interior spaces. However, they don't work as well as exterior shading devices because the air behind the shading device warms up. Eventually, this warm air circulates into the room.

Interior shades still can reduce interior temperatures somewhat by keeping the sun's rays away from high thermal mass materials, such as concrete floors.



Recommended Technique: Use high performance glazing on windows exposed to the sun.

Sunlight allowed to pass through a window brings both visible light and heat. The *Visible Light Transmission Coefficient (VLTC)* measures the amount of visible light admitted through a window. The higher the VLTC, the greater the light transmission. The amount of solar radiation admitted through a window is measured by the *Solar Heat Gain Coefficient (SHGC)*. The lower the SHGC, the less heat transmitted. High performance or *spectrally selective glazing* reduces the heat transmitted through the window while permitting high levels of visible light to pass through. As a result, high performance glazing can reduce cooling energy needs while reducing electrical lighting needs. Such glazing also reduces the fading of interior furnishings due to ultraviolet radiation.

You will not enjoy the benefits, however, unless you choose glazing that is designed for Hawaii's tropical climate. Many *low emissivity (Low-e)* glazing systems are designed for temperate (mainland) climates and aim to keep a home cool in the summer and warm in the winter. Windows designed for temperate climates can actually make homes in Hawaii hotter.

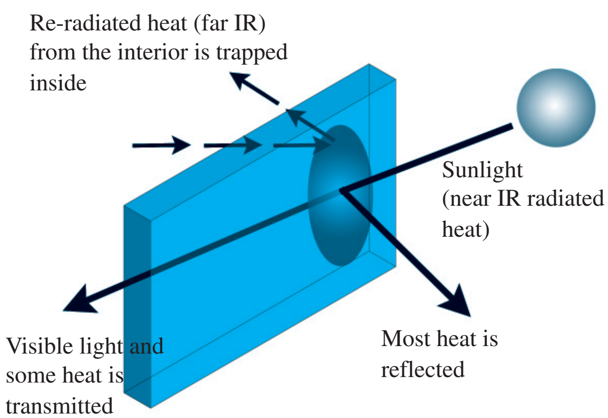


Fig. 10-6: Sunlight and Low-e Glazing (Temperate Climates).

Low-e glazing designed for temperate climates reflect far IR heat back into the house to keep the home warm in winter. The coating reflects both near and far IR radiation.

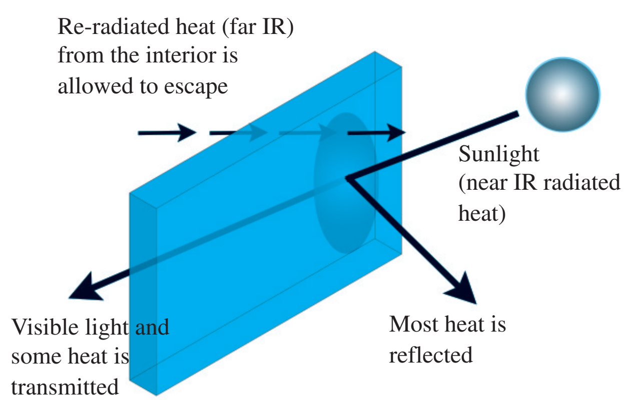


Fig. 10-7: Sunlight and Low-e Glazing (Tropical Climates).

Low-e glazing suitable for Hawaii allows interior heat to escape as well as reflects exterior heat. The coatings reflect near IR and transmit far IR radiation.

Unfortunately, Low-e glazing designed for Hawaii is still expensive and does not perform as well when compared to a well-shaded window.

It is important not to confuse Low-e and spectrally selective coatings with tinting. Tints do not reflect near infrared radiation. They absorb it. As the tint absorbs radiation it will get warmer and eventually re-radiate the energy as heat. In effect, the tint becomes a heat source. Some dark tints actually admit more heat than visible light. For example, a dark gray tint can have a high SHGC of 0.58 and a low VLTC of 0.30. In addition, tinted glass can make a room feel gloomy, and result in higher lighting bills. Conversely, low-e and high performance glazing such as green and blue tints transmit more visible light than heat. Table 10-B shows the heat gain (SHGC) and light transmittance (VLTC) for various glazing types.

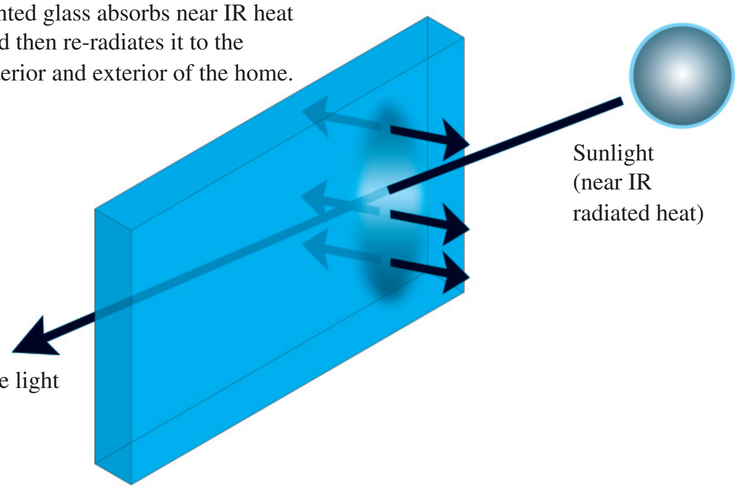


Fig. 10-8: Sunlight and Tinted Window Glazing.

Tinted windows absorb near infrared radiation, becoming a heat source.

Table 10-B Comparison of Glazing Type, Heat Gain, and Light Transmittance.

Glass type	**Solar Heat Gain Coefficient (SHGC)**	**Visible Light Transmittance (VLTC)**
Single Pane Glazing– Standard Glass		
Clear	0.85	0.90
Bronze	0.72	0.67
Gray	0.68	0.60
Dark Gray	0.58	0.30
Single Pane Glazing– Spectrally Selective Glass		
Standard Green Tint	0.70	0.83
High Performance Green Tint	0.61	0.76
High Performance Blue Tint	0.57	0.77
Double Pane Glazing		
Clear	0.76	0.81
Standard Low-e Coating	0.65	0.76
Spectrally Selective Low-e Coating	0.38	0.71

Here are some tips for selecting high performance windows:

- Seek a Solar Heat Gain Co-efficient (SHGC) of .65 or *less*.
- Seek a Visible Light Transmission Co-efficient (VLTC) of .7 or *more*.
- Look for a U-value *equal to or less* than 0.45, which corresponds to an R-value *equal to or greater* than 2.22.
- For air conditioned homes, make sure the Air Leakage Rate (ALR) is 0.2 *or less.* (*ALR* measures the air leakage for windows subjected to a wind of 25 mph. The lower the ALR the better the window seal. ALRs are reported per area for fixed windows, and per opening length for operable windows.)
- If you want to go the extra mile, look for frame and sash materials that contain non-toxic, recycled, or recyclable materials. New eco-labels (such as Green Seal) certify windows that are extra energy-efficient and are produced or shipped in an environmentally responsible manner.
- Windows with Low-e and spectrally selective coatings can be obtained from a large number of manufacturers. Use the standards listed above to ensure that windows are designed for a tropical (Hawaiian) climate.

Recommended Technique: Limit area of openings.

The total area of glazed openings will greatly affect the amount of light and solar heat gain transmitted into a home. Large windows can provide beautiful views and create dramatic spaces, but they can also result in significant heat gain. Larger windows require more shading or better performing glazing. The size of a window should be balanced against how much solar heat gain it will admit.

Recommended Technique: Use skylights with great care.

Skylights are an attractive way to bring natural daylight into a home. However, unless they are designed properly, skylights can cause glare and result in heat gain. For more information on skylights and their design, see Chapter 14.

Chapter 11: Airflow Around Buildings

Natural ventilation refers to the process of exchanging warm building air for cooler outside air without the use of energy-consuming mechanical devices, such as fans and air conditioners. Used in conjunction with insulation and/or radiant barriers, natural ventilation can reduce or eliminate the need for air conditioning in residential construction. To maximize opportunities for natural ventilation *inside* the home, you must make sure your building has unrestricted access to the breezes *outside*. (See Chapter 12 for more information about designing the interior of your home for natural ventilation.)

Recommended Technique: Orient buildings to maximize the cooling potential of prevailing winds.

Use open, elongated, or segmented plans, which are set at a slight angle to prevailing winds with the narrow building ends facing east and west. This approach will reduce solar heat gain on east and west facades and will provide maximum opportunities for cross ventilation.

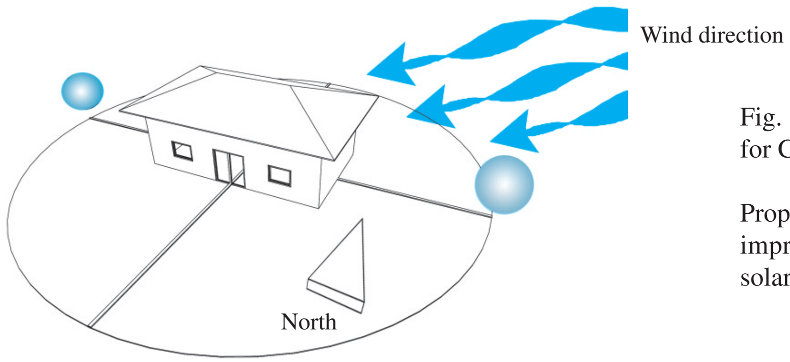


Fig. 11-1: Building Orientation for Cooling.

Proper building orientation will improve cross ventilation and solar control.

Recommended Technique: Provide ample spacing between buildings in the direction of wind flow.

Spacing buildings by a distance of at least five times the height of the upwind building provides greater natural ventilation opportunities for the down wind building.

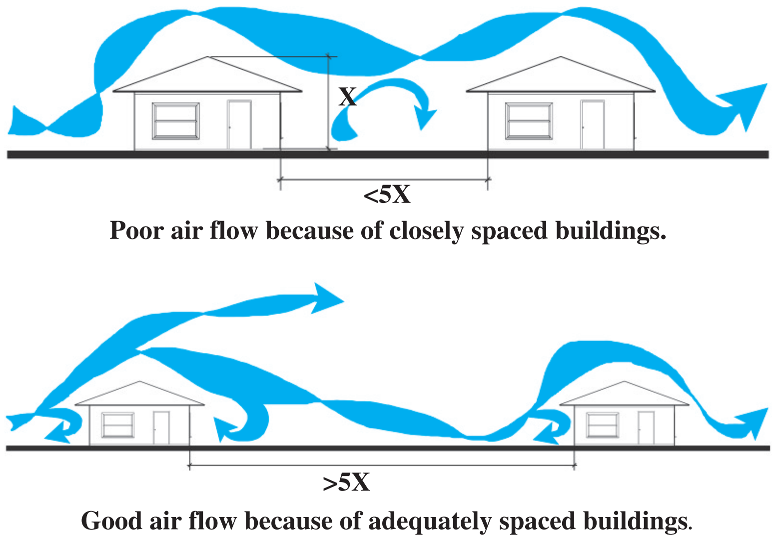
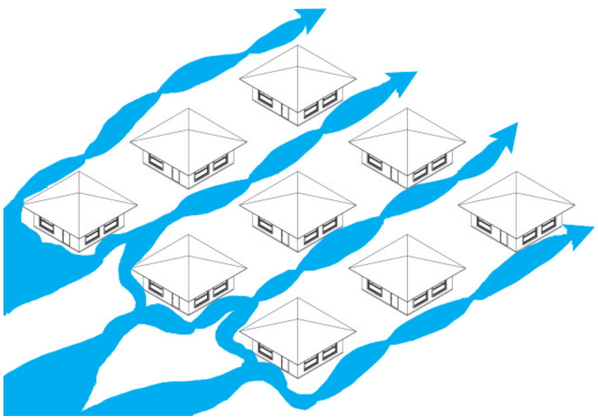


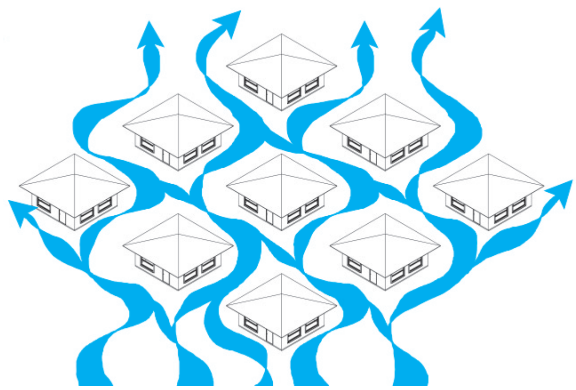
Fig. 11-2: Spacing of Multiple Buildings for Cooling.

Recommended Technique: Arrange buildings to provide for good air flow around all structures.

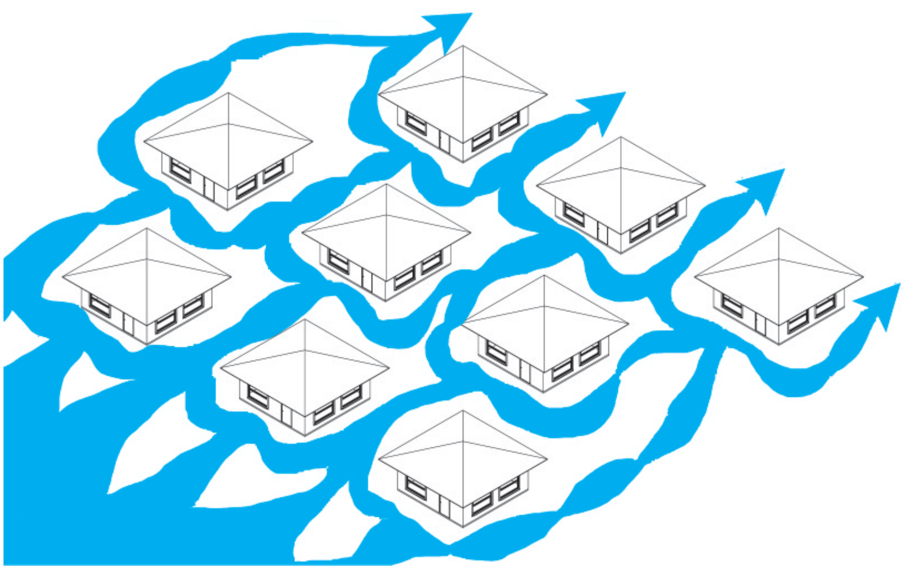
Air flow around a building creates a high-pressure zone on the windward face and low-pressure zones on the leeward face and on sides that are parallel to the wind direction. Buildings aligned with the wind direction create "wind shadows" and poor ventilation conditions. Ventilation around buildings can be improved by orienting the buildings at an angle to the predominant wind direction. This can also increase the effective distance between the buildings.



A linear arrangement of homes lined up parallel to the wind direction creates poor airflow.



A linear arrangement of homes lined up at an angle to the wind direction provides good airflow.

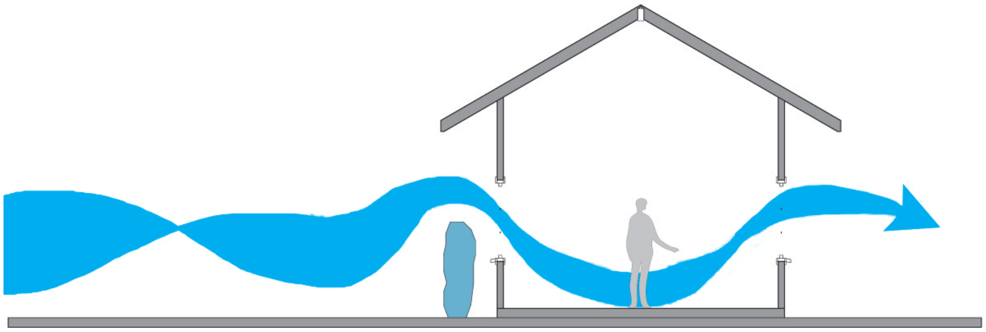


A staggered arrangement of homes creates good airflow regardless of wind direction.

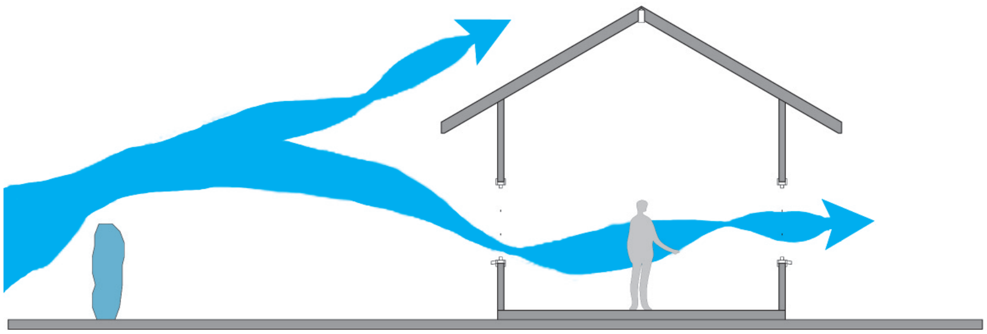
Fig. 11-3: Arranging Multiple Buildings for Good Air Flow.

Recommended Technique: Use landscaping elements to improve air flow around structures.

Plantings or bermed and built elements, such as trees, hedges, fences, and garden walls, can direct breezes to improve natural ventilation.



Hedges or planting close to a house can restrict airflow and deflect breezes downward.



Better airflow is achieved with hedges farther from the home.

Fig. 11-4: Using Landscaping to Improve Air Flow Around Structures.

Select and prune trees to allow air to flow freely at window levels. Monkeypod trees are wonderful models for energy efficient building design. The tree's sheltering canopy shades surrounding surfaces, reduces radiant heat, provides adequate views, and allows for cooling breezes to penetrate from the sides.

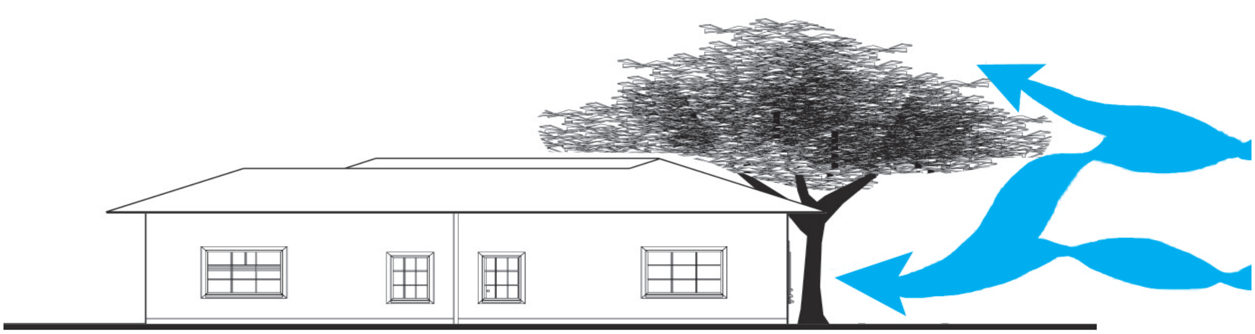


Fig. 11-5: Using Landscaping for Cooling.
Landscaping can keep homes cool by shading and directing airflow.

Chapter 12: Airflow in Buildings

As we mentioned in Chapter 11, *natural ventilation* refers to the process of exchanging warm building air for cooler outside air without the use of energy-consuming mechanical devices, such as fans and air conditioners. To maximize opportunities for natural ventilation in the home, you must orient the building for maximum access to outside breezes as discussed in Chapter 11, and your design must provide openings that will encourage cross-ventilation inside the home. The primary strategies for creating effective cross ventilation inside the home are:

- Provide an adequate number of windows
- Design for optimum window type, size, and placement
- Use ceiling fans where required to improve airflow.

Floor Plan Design and Orientation

Recommended Technique: Design floor plans that provide effective natural ventilation and good air circulation at body level.

For adequate ventilation, there should be at least two operable openings to the outside in each space. Operable openings include operable windows and entries (doors). Entries should have screen doors. Solid doors should be provided with a door catch to hold them open. Two common window configurations are: openings on adjacent walls (A), and openings on opposite walls (B) (see Figure 12-1). Spaces with only one exterior wall are difficult to ventilate effectively. In this situation casement windows or a wing wall may be used to improve ventilation (C).

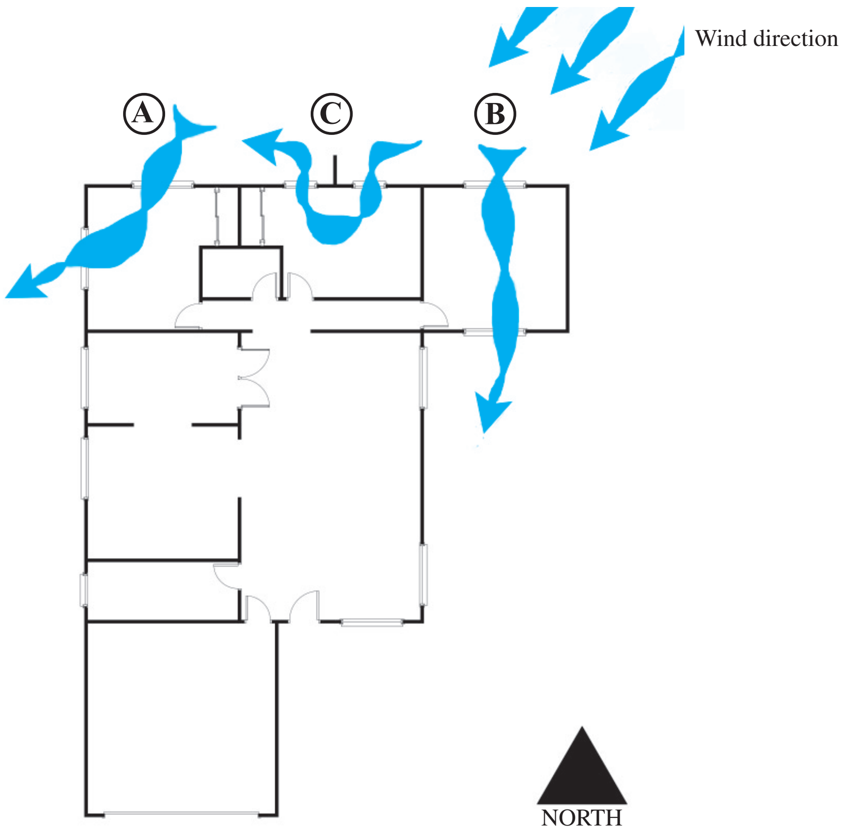


Fig. 12-1: Basic Natural Ventilation Strategies.

Open floor plans enhance air flow and daylighting of interior spaces. Narrow cross sections also improve air flow and daylight penetration. Staggered configurations or building wings can be used to improve air circulation throughout the home (see Figure 12-2).

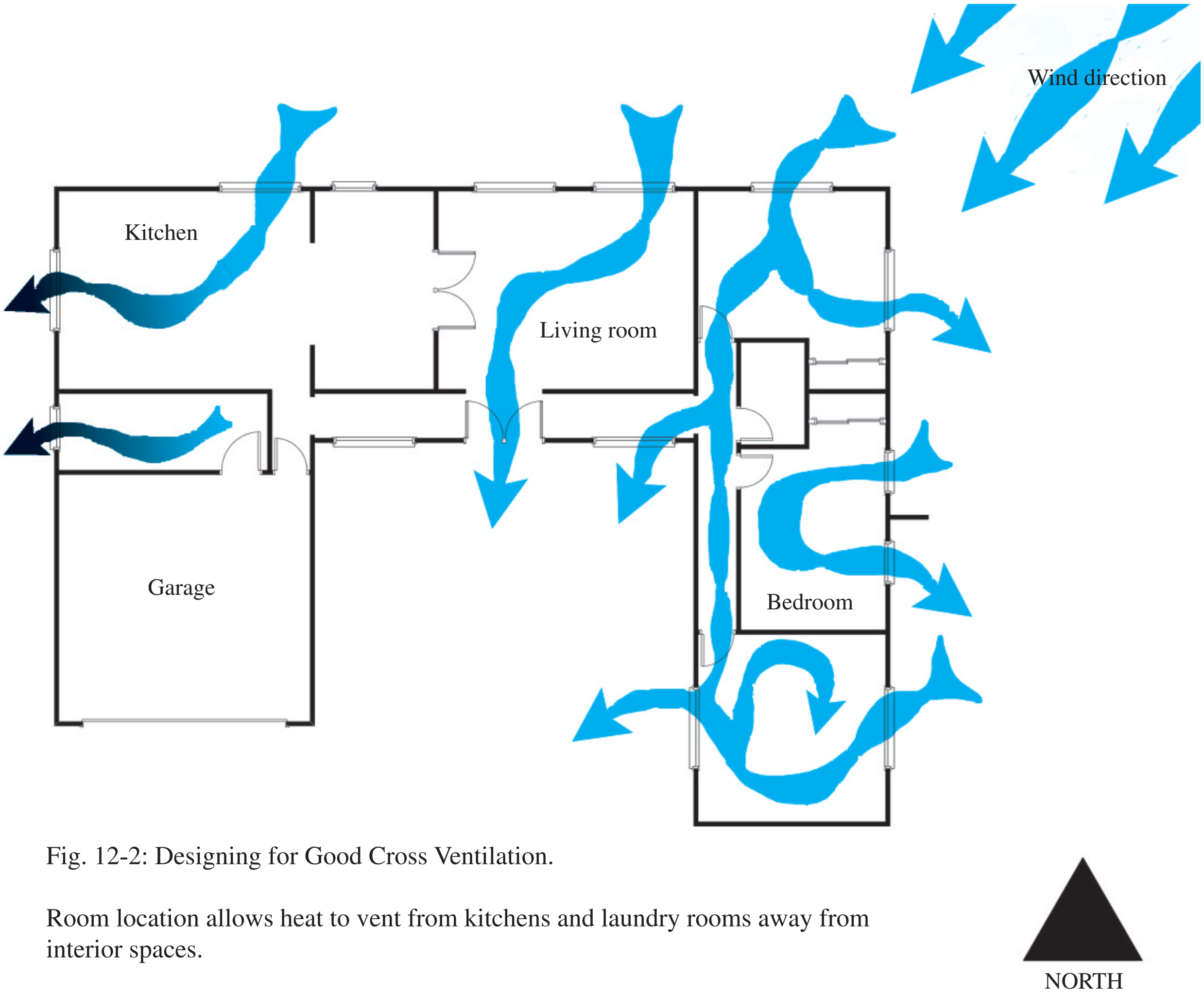


Fig. 12-2: Designing for Good Cross Ventilation.

Room location allows heat to vent from kitchens and laundry rooms away from interior spaces.

Here are some tips for designing for effective natural ventilation:

- Use open floor plans with a minimum of interior partitions to improve air circulation throughout the home.
- Use louvered doors and shutters to allow air to circulate freely through spaces while maintaining visual privacy.
- Rooms that produce heat and humidity such as kitchens, laundry rooms, and bathrooms require special planning. They should be well ventilated and placed on the leeward side of the house to prevent hot humid air from spreading into other living spaces.
- Protect exterior doors from rain with generous eaves and screens if they are to be used for natural ventilation. Hinged doors should have stops and hold-open devices.
- Use louvers or catches on interior doors.
- Install a ceiling fan for every 400 square feet of floor space to improve comfort levels when breezes are light.
- Separate garages or place them on the leeward side of the home so they do not block needed airflow.

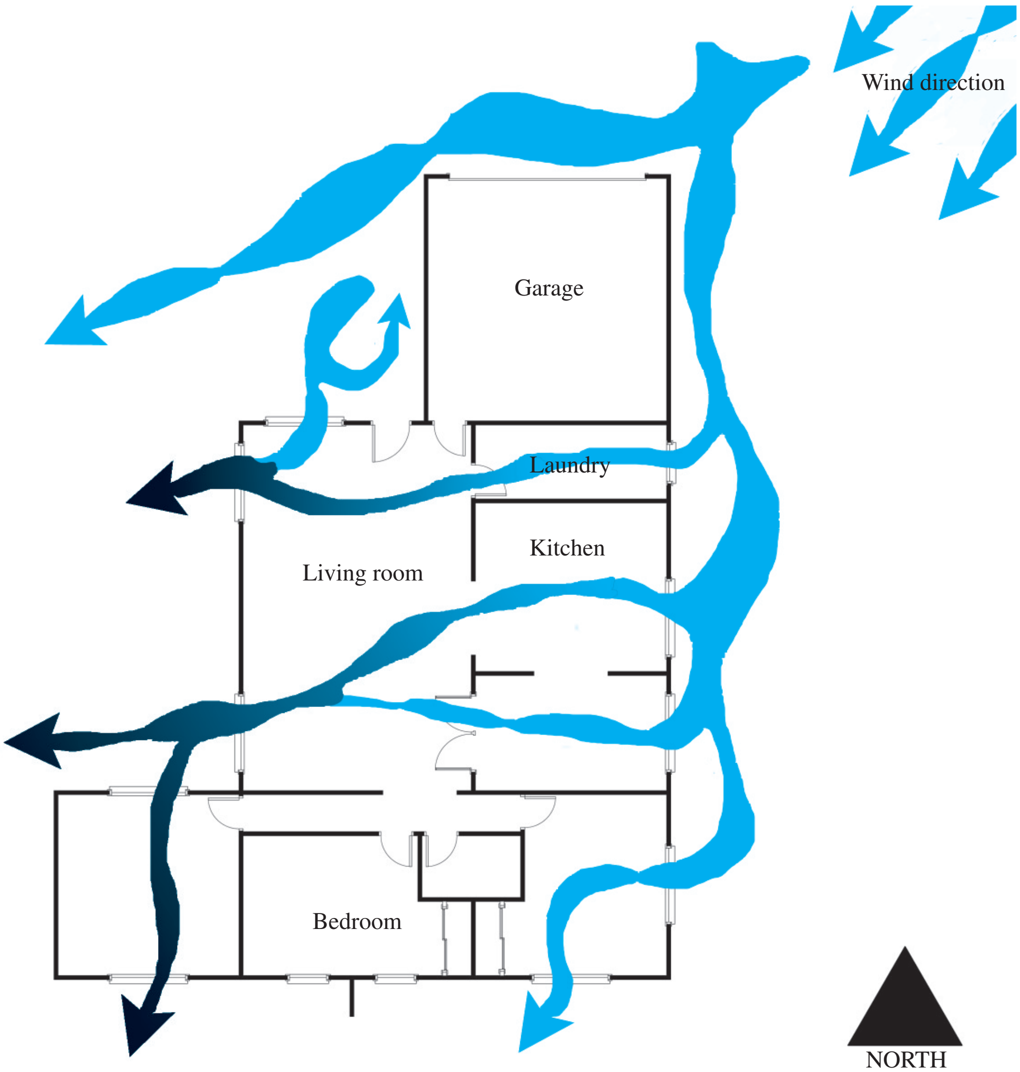


Fig. 12-3: Poor Design for Cross Ventilation.

The garage blocks airflow, and location of kitchen and laundry directs heat from these areas to other occupied spaces.

Recommended Technique: For spaces with openings on opposite walls, orient the room 45^0 from the wind direction.

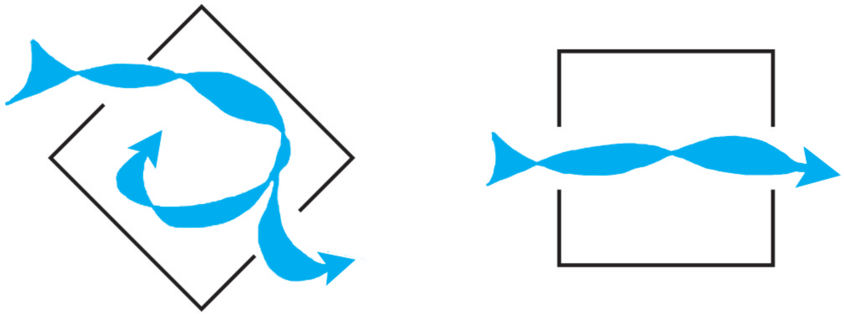


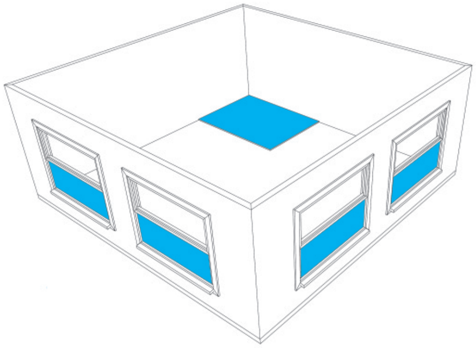
Fig. 12-4: Room Orientation for Improved Air Flow.
Rooms oriented 45^0 relative to the prevailing wind direction will see 20% improved air flow.

Window Type and Size

Windows types vary substantially in their net opening size, the degree of protection they offer from rain, and their ability to direct airflow. All window types should be provided with screens and protected from direct sunlight. To admit sufficient outside air, windows and other operable openings should have a net opening area equal to at least 12% of the room's floor area. Only the area of the window that can be opened is considered towards the 12% (see Figure 12-5). For a list of window types and their net open areas see Figure 12-6. No more than 70% of the opening area should be placed on one wall or to one side of a wing wall.

Fig. 12-5: Window Sizing for Air Flow.

Operable openings should be at least 12% of the floor area.



Single and double hung windows are the least effective window for controlling rain and air flow due to their small open area and vertical orientation. Single hung windows especially are a poor choice since the upper sash, although usually protected by eave overhangs, is not operable and does not allow for ventilation. Sliding windows are also vulnerable to rain. Casement windows have the largest open area but they do not provide as much protection against rain. Awning windows have relatively large open areas and provide good rain protection when open. Awning and jalousie windows have approximately the same open area. Both provide reasonable rain protection, but jalousie windows offer better airflow control.

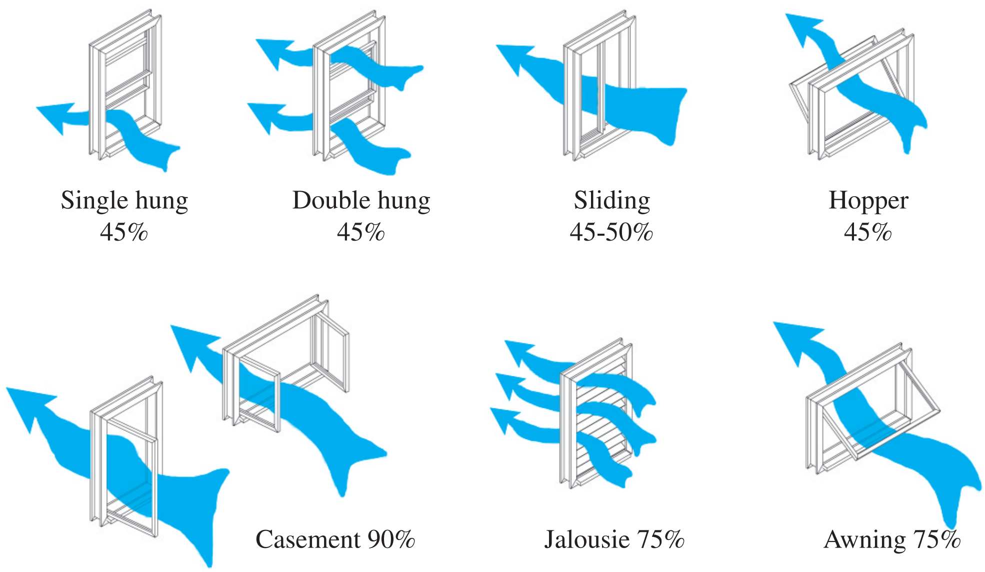


Fig. 12-6: Effective Open Areas for Various Window Types.

Recommended Technique: Keep inlet openings slightly smaller than outlet openings.

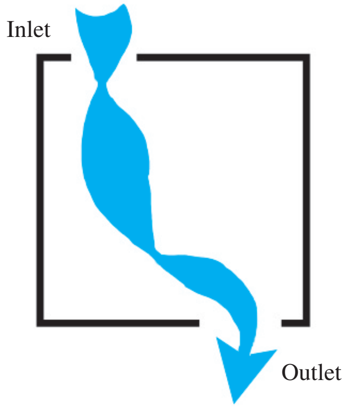


Fig. 12-7: Sizing Inlet and Outlet Openings.

Cross ventilation is optimum well when inlet openings are slightly smaller in total area than outlet openings (1:1.25 is a good ratio).

Recommended Technique: For spaces with openings on adjacent walls, place windows far apart and at a diagonal.

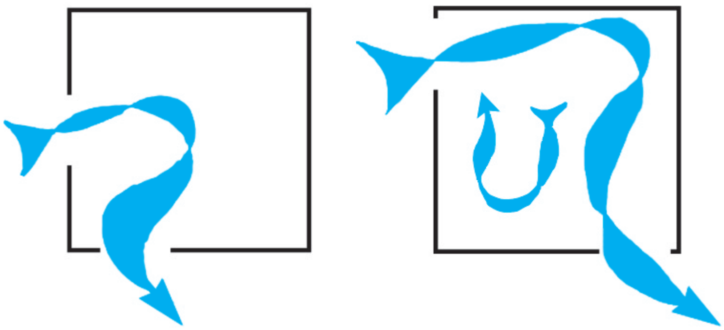


Fig. 12-8: Window Arrangement for Cross Ventilation (Adjacent Walls).

Air flow is limited when windows are placed close together. Improved airflow is achieved when windows are spaced further apart. Casement windows are a better choice in this situation because the window's glazing acts as a small wing wall and maximizes airflow.

Recommended Technique: For spaces with openings on the same wall, use casement windows or wing walls spaced as far apart as possible.

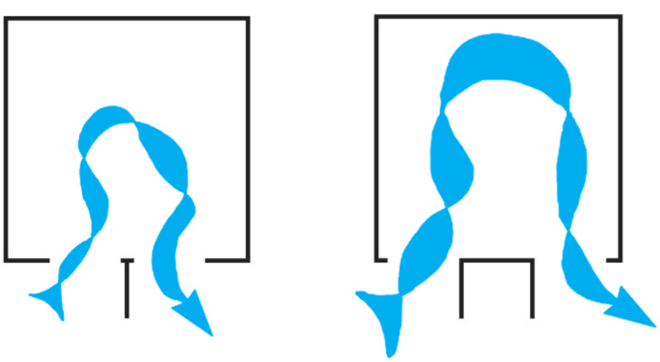


Fig. 12-9: Window Arrangement for Cross Ventilation (Same Wall).

Two wing walls spaced apart perform better than a single wing wall. Casement windows are a good choice in this situation because the window's glazing acts as a wing wall to maximize airflow.

Recommended Technique: Locate windows at body level.

Inlet windows at body level ensures the occupants will enjoy cooling air movement. However, outlet window location does not significantly effect airflow.

Body levels change depending on the activities within the room. For example, lower level vents work best in bedrooms.

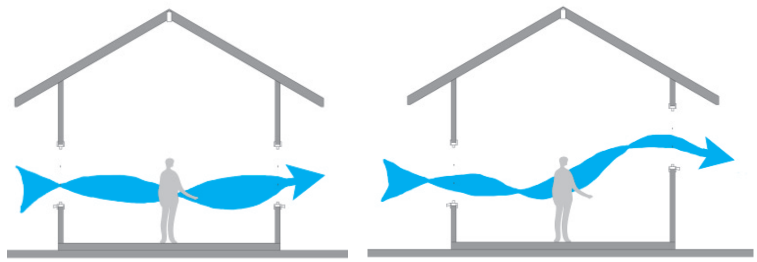


Fig. 12-10: Window Heights and Cross Ventilation (Good Design).

High windows produce poor air movement at body level. A low outlet window does not correct bad airflow in this situation.

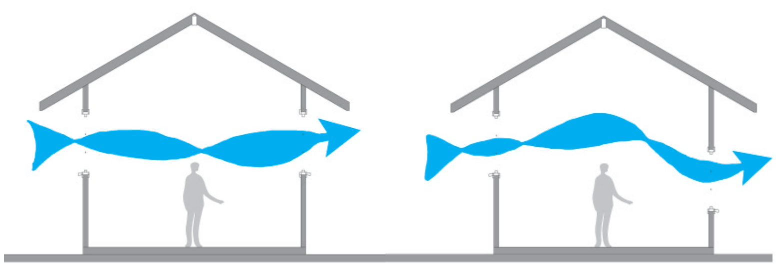


Fig. 12-11: Window Heights and Cross Ventilation (Poor Design).

Window overhangs with a space at the wall produce the best air movement at body level. The gap helps to push air downward increasing airflow at body level.

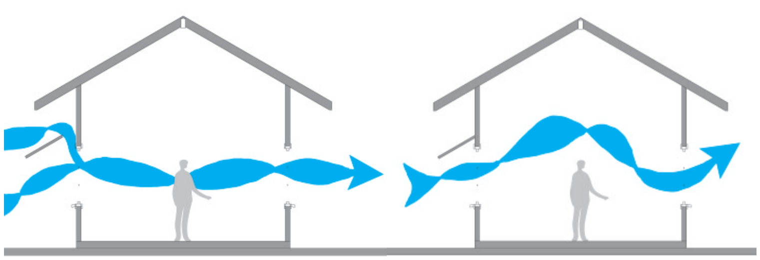


Fig. 12-12: Using Window Overhangs to Assist Ventilation.

Summary of Key Strategies and Recommended Techniques for Section II.

Reduce heat buildup:
- Limit exposure to heat build-up by orienting longer sides of the home north and south.
- Use existing or new landscape elements to shade the site and the roof, walls, and openings.
- Limit the area of unplanted and paved exterior surfaces.
- Use porous paving materials to reduce thermal mass, heat gain, and glare.
- Use light colored materials that will reflect sun's heat rather than absorb and transfer it to the home's interior.
- Insulate the building shell (roof, ceilings, walls).
- Install radiant barriers in the roof and walls.
- Ventilate the roof or attic properly.
- Use high performance glazing on windows exposed to the sun.
- Limit the area of openings (windows, skylights, glass doors) to prevent solar heat gain.

Provide natural ventilation to remove heat and humidity from building interiors:
- Orient buildings to maximize the cooling potential of prevailing winds.
- Provide ample spacing between buildings in the direction of wind flow so that all structures have good airflow.
- Arrange buildings to provide for good airflow around all structures.
- Use landscaping elements such as trees, fences and hedges to improve airflow around structures.
- Design floor plans that provide effective cross ventilation and good air circulation at body level.
- For spaces with openings on opposite walls, orient the room 45^0 from the wind direction.
- Keep inlet openings slightly smaller than outlet openings.
- For spaces with openings on adjacent walls, place windows far apart and at a diagonal.
- For spaces with openings on the same wall, use casement windows or wing walls spaced as far apart as possible.
- Locate windows at body level.